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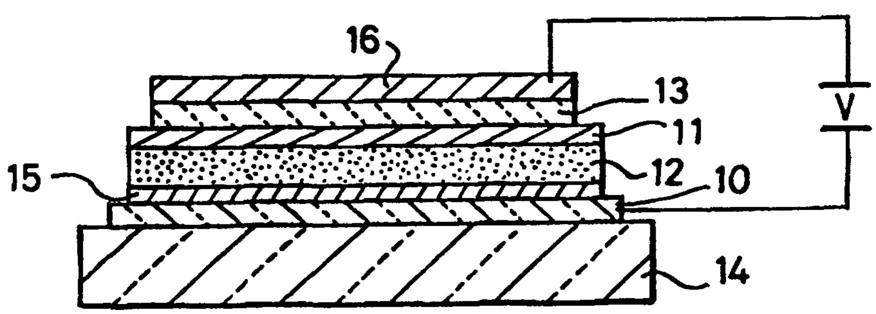
(57) Abstract

A light–emissive device comprising: a light–emissive region (12); a first electrode (10) located on a viewing side of the light–emissive region for injecting charge carriers of a first type; and a second electrode (11) located on a non–viewing side of the light–emissive region for injecting charge carriers of a second type; and wherein there is a reflectivity–influencing structure (13) located on the non–viewing side of the light–emissive region and including a light absorbent layer comprising graphite and/or a fluoride or oxide of a low work function metal.



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DISPLAY DEVICES

This invention relates to display devices.

One specific class of display devices is those that use an organic material for light emission. Light-emissive organic materials are described in PCT/WO90/13148 and US 4,539,507, the contents of both of which are incorporated herein by reference. The basic structure of these devices is a light-emissive organic layer, for instance a film of a poly(p-phenylenevinylene ("PPV"), sandwiched between two electrodes. One of the electrodes (the cathode) injects negative charge carriers (electrons) and the other electrode (the anode) injects positive charge carriers (holes). The electrons and holes combine in the organic layer generating photons. In PCT/WO90/13148 the organic light-emissive material is a polymer. In US 4,539,507 the organic light-emissive material is of the class known as small molecule materials, such as (8-hydroxyquinoline)aluminium ("Alq3"). In a practical device one of the electrodes is typically transparent, to allow the photons to escape the device.

Figure 1 shows the typical cross-sectional structure of an organic light-emissive device ("OLED"). The OLED is typically fabricated on a glass or plastic substrate 1 coated with a transparent first electrode 2 such as indium-tin-oxide ("ITO"). Such coated substrates are commercially available. This ITO-coated substrate is covered with at least a layer of a thin film of an electroluminescent organic material 3 and a final layer forming a second electrode 4, which is typically a metal or alloy. Other layers can be added to the device, for example to improve charge transport between the electrodes and the electroluminescent material.

If light that is incident on the display can be reflected back towards a viewer, especially from the region of pixels that are intended to appear dark, then the apparent contrast between the pixels of the display can be reduced. This reduces the effectiveness of the display.

Many display devices are used in applications where power consumption is a crucial consideration - examples are battery-powered devices such as portable computers and mobile phones. There is therefore a drive to improve the efficiency of display devices.

According to one aspect of the present invention there is provided a light-emissive device comprising: a light-emissive region; a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type; and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light absorbent layer comprising graphite and/or a fluoride or oxide of a low work function metal.

According to a second aspect of the present invention there is provided a light-emissive device comprising: a light-emissive region; a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type; and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light-reflective layer and a light-transmissive spacing layer between the second electrode and the light-reflective layer, the thickness of the spacing layer being such as to space a reflective plane of the light-reflective layer by approximately half the wavelength of the optical mode of the device from at least part of the light-emissive region.

The first electrode is preferably at least partially light-transmissive, most preferably substantially transparent, at least to light of some or all of the wavelengths that can be emitted from the device. The first electrode could, for example, be formed of ITO (indium-tin oxide), TO (tin oxide) or gold. The first electrode is preferably disposed in a viewing direction from the light-emissive

region - that is between the light-emissive region and an expected location of a viewer. The first electrode may be in the form of a layer. Where the device includes more than one pixel more than one first electrode could be provided to allow (in co-operation with the second electrode) each pixel to be individually addressed.

The second electrode may be at least partially light-transmissive, suitably substantially transparent, at least to light of some or all of the wavelengths that can be emitted from the device. This could be achieved by forming the second electrode from a light-transmissive material and/or by the second electrode being relatively thin, for example less than 2, 5, 10, 20 or 30nm in thickness. Suitable materials for the second electrode include lithium, calcium and ITO. Alternatively, the second electrode could be reflective or non-reflective/light absorbent. In that case, the second electrode preferably itself provides the reflectivity-influencing structure. Where the second electrode is light-absorbent it could be formed of a light-absorbent materials such as a fluoride or oxides of a low work function metal such as Li, Ca, Mg, Cs, Ba, Yb, Sm etc. (together, optionally, with a conductive material such as Al, which could be co-deposited with the oxide or fluoride), or of a low work function metal incorporating and preferably co-deposited with a light-absorbent material such as carbon (graphite). The said low work function metal may have a work function below 4.0eV. The said low work function metal may have a work function below 3.5eV. The said low work function metal may have a work function below 3.2eV. The said low work function metal may have a work function below 3.0eV. A suitable range of thickness for the second electrode is in the range from 50 to 1000nm, preferably from 100 to 300 nm.

The first electrode and/or the second electrode preferably comprise electrically conductive material, for example metallic material. One of the electrodes (the hole-injecting electrode) preferably has a work function of greater than 4.3 eV. That layer may comprise a metallic oxide such as indium-tin oxide ("ITO") or tin oxide ("TO") or a high work function metal such as Au or Pt. This may be the first electrode or the second electrode. The other electrode (the electron-injecting

electrode) preferably has a work function less than 3.5 eV. That layer may suitably be made of a metal with a low work function (Ca, Ba, Yb, Sm, Li etc.) or an alloy or multi-layer structure comprising one or more of such metals together optionally with other metals (e.g. Al). This may be the second electrode or the first electrode. The rear electrode is preferably at least partially light-absorbent. This may be achieved by incorporating a layer of light-absorbent material such as carbon in the electrode. Such material is preferably also electrically conductive.

The reflectivity-influencing structure could be located adjacent the second electrode. The reflectivity-influencing structure then suitably influences the reflectivity of the rear (non-viewing side) of the device, being (for example) substantially light-absorbent or substantially light-reflective. The reflectivity-influencing structure may include distinct substantially light-absorbent and substantially light-reflective areas.

In the first aspect of the invention the reflectivity-influencing structure may comprise a light-absorbent layer. Such a layer is suitably for reducing reflection by or through the second electrode of light emitted from the light-emissive region and/or absorbing light that has been transmitted through the second electrode and/or absorbing light that is incident on the device from another source. Such a light-absorbent layer is preferably located adjacent to the second electrode; alternatively the light-absorbent layer could be spaced from the second electrode, for example by an insulating material. The presence of the reflectivity-influencing structure adjacent or more generally behind the second electrode suitably renders the second electrode substantially non-reflective to light emitted from the light-emissive region. Such a light-absorbent layer is preferably formed from a light-absorbent material - for example the light-absorbent layer of the reflectivity-influencing structure could comprise graphite. Where the device comprises a plurality of individual pixels the light-absorbent layer is preferably common to a plurality of pixels.

In the second aspect of the invention the reflectivity-influencing structure may comprise a light-reflective layer. Such a layer is suitably for influencing the coincidence within the device of the optical field (e.g. an anti-node of the optical field) and a part of the light-emissive region. Such a part of the light-emissive region is suitably a region at which there is some or significant electron/hole recombination (preferably to generate photons). The said part is preferably a principal recombination site or plane of the light-emissive layer. The said part is most preferably the peak recombination site or plane of the device. The reflectivity-influencing structure preferably comprises a light-transmissive spacing layer between the second electrode and such a light-reflective layer, suitably for spacing the light-reflective layer from the light-emissive layer and preferably by a predetermined spacing. The spacing layer could be provided by material integral with the second electrode itself - for example by virtue of the thickness of the second electrode. The thickness of the spacer is preferably such as to space a reflector of the reflection-influencing structure from at least part of the light-emissive region by approximately half the wavelength of the optical mode of the device. That reflector may be one of the major surfaces of the reflective layer (those closer to and further from the light-emissive layer) or may be a reflective structure (such as a distributed Bragg reflector) defined by the reflective layer. The thickness of the spacer is most preferably such as to space the reflector by approximately or substantially half the wavelength of the optical mode of the device from the region of the light-emissive region at which the optical field is approximately or substantially at its peak.

The light-absorbent or light-reflecting layers mentioned above of the reflection-influencing structure are preferably in optical communication with the light-emissive layer of the device so that light from the light-emissive layer may reach the light-absorbent or light-reflecting layers.

The reflection-influencing structure is preferably electrically conductive, suitably to permit electrical contact to be made to the second electrode through the reflection influencing structure.

According to a third aspect of the present invention there is provided a light-emissive device comprising: a light-emissive region; a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type; and a contrast enhancing structure located on the non-viewing side of the light-emissive region and including a reflective structure having different reflectivity for different wavelengths of incident light, and having a reflectivity peak encompassing an emission wavelength of the light-emissive region. In this aspect of the invention the reflective structure is suitably a distributed Bragg reflector. In this aspect of the invention the second electrode suitably comprises a layer located on the non-viewing side of the reflective structure and a plurality of through paths passing through the reflective structure for electrical conduction between the said layer of the second electrode and the light-emissive region. The through paths preferably occupy less than 15% or less than 10% of the emissive area of the device. The through paths may occupy between 15% and 5% of the emissive area of the device. In this aspect of the invention the cathode may comprise a transparent layer located between the reflective structure and the light-emissive region. That transparent layer may be in contact with the through paths.

In general, the light-emissive material is suitably an organic material and preferably a polymer material. The light-emissive material is preferably a semiconductive and/or conjugated polymer material. Alternatively the light-emissive material could be of other types, for example sublimed small molecule films or inorganic light-emissive material. The or each organic light-emissive material may comprise one or more individual organic materials, suitably polymers, preferably fully or partially conjugated polymers. Example materials include one or more of the following in any combination: poly(p-phenylenevinylene) ("PPV"), poly(2-methoxy-5(2'-ethyl)hexyloxyphenylene-vinylene) ("MEH-PPV"), one or more PPV-derivatives (e.g. di-alkoxy or di-alkyl derivatives), polyfluorenes and/or co-polymers incorporating polyfluorene

segments, PPVs and related co-polymers, poly(2,7-(9,9-di-n-octylfluorene)-(1,4-phenylene-((4-secbutylphenyl)imino)-1,4-phenylene)) ("TFB"), poly(2,7-(9,9-di-n-octylfluorene) - (1,4-phenylene-((4-methylphenyl)imino)-1,4-phenylene-((4 - methylphenyl)imino) - 1,4-phenylene)) ("PFM"), poly(2,7 - (9,9 - di-n-octylfluorene) - (1,4-phenylene-((4-methoxyphenyl)imino)-1,4-phenylene- ((4-methoxyphenyl)imino)-1,4-phenylene)) ("PFMO"), poly (2,7-(9,9-di-n-octylfluorene) ("F8") or (2,7-(9,9-di-n-octylfluorene)-3,6-Benzothiadiazole) ("F8BT"). Alternative materials include small molecule materials such as Alq3.

One or more charge-transport layers may be provided between the light-emissive region and one or both of the electrodes. The or each charge transport layer may suitably comprise one or more polymers such as polystyrene sulphonic acid doped polyethylene dioxythiophene ("PEDOT-PSS"), poly(2,7-(9,9-di-n-octylfluorene)-(1,4-phenylene-(4-imino(benzoic acid))-1,4-phenylene-(4-imino(benzoic acid))-1,4-phenylene)) ("BFA"), polyaniline and PPV.

Any implied physical orientation of the device is not necessarily related to its physical orientation during use or manufacture.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

figure 2 is a cross-section of a first device;

figure 3 is a plan view of a second device;

figure 4 is a cross-section of the device of figure 3 on the line A-A'; and

figure 5 is a cross-section of a third device;

figure 6 is a plan view of a fourth device;

figure 7 is a cross-section of the fourth device; and

figure 8 shows the reflectivity of a DBR against wavelength.

The figures are not to scale.

The device of figure 2 comprises an anode electrode layer 10, and a cathode electrode 11. Located between the electrode layers is a layer 12 of light- missive

material. The anode electrode is formed of transparent ITO. The cathode electrode is formed of calcium. The cathode is sufficiently thin that it is not significantly reflective. Behind the cathode is a layer 13 of carbon. When a suitable voltage is applied across the electrodes light is emitted from the light-emissive material substantially omnidirectionally. Some of the light is emitted forwards towards the anode and passes directly out of the device through the anode. Some of the light is emitted backwards towards the cathode. Incident light that shines on to the display from an external source can be absorbed by the carbon layer 13. Because this light is absorbed it does not reflect back towards a viewer - this can improve the effect produced by the display, as described in detail below.

The device of figure 2 may be formed starting with a commercially-available glass sheet coated with ITO. The glass sheet (14 in figure 2) forms the substrate for subsequent deposition steps. The glass sheet could be a sheet of sodalime or borosilicate glass of a thickness of, for instance, 1mm. Instead of glass other materials such as Perspex could be used. The thickness of the ITO coating is suitably around 100 to 150nm and the ITO suitably has a sheet resistance of between 10 and 30 */Ø. Over the ITO anode is deposited a hole transport or injecting layer 15. The hole transport layer is formed from a solution containing PEDOT:PSS with a ratio of PEDOT to PSS of around 1 to 5. The thickness of the hole transport layer is suitably around 50nm. The hole transport layer is spin-coated from solution and then baked typically at 200°C for 1 hour in a nitrogen environment. Then an electroluminescent layer 12 comprising 20% TFB in 5BTF8 is coated over the hole transport layer by spin-coating typically to a thickness of 90nm. The term 5BTF8 refers to poly (2,7-(9,9-di-*n*-octylfluorene) ("F8") doped with 5% poly-(2,7-(9,9-di-*n*-octylfluorene)-3,6-benzothiadiazole) ("F8BT"). Then a transparent or semitransparent layer of a low work function material such as calcium is thermally evaporated on to the electroluminescent layer in vacuo at a base pressure of less than 10^{-8}mbar to form the cathode layer 11. The thickness of this layer is preferably greater than around 1nm but less than the thickness at which the calcium layer would be non-transparent - typically around 20nm. Over

this layer is deposited by electron beam evaporation a layer 13 of carbon with a thickness of between 100 and 500nm at base pressures less than 10^{-8}mbar. On this layer is deposited by sputter deposition a layer 16 of aluminium with a thickness of between 100 and 1000nm at base pressures less than 10^{-8}mbar. In this embodiment the low work function layer 11 is chosen to act as an efficient electron injector for injecting electrons into the light-emissive region. The carbon layer 13 acts as a light-absorbing layer yet has a conductivity that is low enough not to significantly increase the drive voltage of the device. The sputtered aluminium layer 16 acts as an encapsulant, having a compact morphology with low pinhole density and small grain size. Contacts can be attached to the device (between layers 16 and 10) and it can finally be sealed in epoxy resin for environmental protection.

Figures 3 and 4 show a multi-pixel display device that makes use of the principle described above in connection with the device of figure 2. The device of figures 3 and 4 comprises a set of parallel anode electrode strips 20 in a common anode plane and a set of parallel cathode electrode strips 21 in a common cathode plane spaced from the anode plane. Between the anode and cathode electrodes is a light-emissive layer 22. The areas where anode and cathode electrode strips overlap define pixels of the display device. By using a passive matrix addressing scheme individual pixels can be caused to emit light. (The device could alternatively be configured to allow active matrix or other addressing schemes to be used). Figure 4 shows that each cathode electrode comprises three layers: an injection layer 75 of a low work function material such as calcium adjacent to the emissive layer 22, an intermediate layer 76 of a light-absorbent material such as carbon (graphite) and a conduction layer 77 of a highly conductive material such as aluminium. Together these make up a cathode plane 81. In general, the injection layer is suitably of a material that has good properties of injection into the light-emissive layer 22; the intermediate layer is suitably of a material that has good light-absorbency properties and the conduction layer is of a highly conductive material. The conduction layer may be significantly thicker than the other layers and preferably helps to distribute charge evenly along the electrode

structure. Where the material chosen for one of the layers can also perform the function of another layer then that other layer could be omitted. For instance, if the selected light emissive material were one into which good charge injection could be achieved from carbon then the layer 75 could be omitted, and/or if the layers 75 and/or 76 provided adequate conduction then the layer 77 could be omitted. The light absorbent layer 76 preferably lies between the other two layers (where present), in which case it should be electrically conductive, but it could lie behind the other two layers Alternatively, or in addition, a light absorbent layer covering the whole structure could be provided (layer 29 in figure 4). If that layer were of a conductive material such as carbon then an insulating layer 23 could be provided to prevent shorting between the cathode strips 21.

The effect of the light-absorbent layer 76 is to absorb light that is incident on the display and could otherwise be reflected from the display causing a reduction in contrast. This is illustrated by light rays 80 in figure 4, which are absorbed by layers 23 and 29. The light-absorbent layer therefore helps to increase contrast. The light-absorbent layer may also help to reduce transmission within the device itself of light emitted from the light-emissive layer 22. This can help to increase contrast by avoiding such light emerging from the device at a location where it appears to come from a different pixel from the one from which it was emitted.

One of the contacts from the display driver is applied to the layer 77.

A carbon layer or other non-reflective layer could also be provided in front of the light-emissive layer 22 in the lateral spaces between the pixels to further reduce reflection of ambient light.

The principles described above in relation to the devices of figures 2 to 4 can therefore improve contrast between adjacent pixels of a device and improve the pattern of light emission from a single pixel by reducing emission of more obliquely angled light and reducing reflection of ambient light.

Figure 5 shows another display device. The device of figure 5 comprises an anode electrode layer 40, and a cathode electrode 41. Located between the electrode layers is a layer 42 of light-emissive material. The anode electrode and the cathode electrode are formed of transparent ITO. Alternatively, for example, the electrodes could be formed from a thin layer of a low work function metal such as calcium adjacent to an transparent spacing layer formed from a material such as ITO, ZnSe, ZnS etc.). When a suitable voltage is applied across the electrodes light is emitted from the light-emissive material substantially omnidirectionally. Some of the light is emitted forwards towards the anode and passes directly out of the device through the anode. Some of the light is emitted backwards towards the cathode, through which it passes into a reflection structure indicated generally at 43. The reflection structure comprises a reflective layer 44 and a transparent spacing layer 46. The spacing layer lies between the cathode 41 and the reflective layer 44 and spaces the reflective layer from the light-emissive region 42. The reflective layer reflects backwardly emitted light forwards so that it can pass back through the cathode electrode 41, the light-emissive layer 42 the anode electrode 40 and the glass substrate 47 and out of the device (see ray 48).

In figure 5 curve 49 illustrates the form of the optical field and region 50 illustrates the zone in the device at which electron/hole recombination to generate photons is most intense. The equivalent features are illustrated at 60 and 61 respectively for the device of figure 1. The thickness of the spacing layer in the device of figure 5 is ideally chosen so that the plane (or one of the planes) of the reflective layer 44 that acts to return backwardly emitted light is spaced from the emissive layer by a distance such that at at least one emission frequency of the device the peak of the optical mode of the whole reflective arrangement (see curve 49) coincides with the region of peak electron/hole recombination in the light-emissive layer of the device. The effect of this is to arrange that the area of light generation in the device is at a more efficient plane of the device of figure 5 than in the device of figure 1, by tuning the peak of the optical field (anti-node) to coincide with the hole/electron recombination zone of the emissive layer. This optimises (or at least partially optimises) the location for efficient light generation for a given

wavelength. The wavelength for which the device is optimised preferably is or is near the peak intensity emission wavelength. This ideal arrangement calls for very precise spacing of the respective layers; however, considerable benefits can be gained by arranging the layers approximately or substantially in that way.

The device of figure 5 may be formed by a similar route to that described above for the device of figure 2 up to the formation of the cathode electrode. Then for the device of figure 5 the spacing layer 46 is formed by depositing ITO, ZnSe, ZnS or the like to the required thickness, preferably on top of a thin layer of a low work-function metal such as calcium. Over the ITO spacing layer the reflective layer 44 is formed from reflective material such as aluminium. In an alternative embodiment a conducting dielectric stack next to or spaced from the cathode could be used as the reflector. Such a stack could be formed, for example, of alternating layers of ITO and NiO.

In another alternative embodiment, one of the electrodes could be formed of a reflectivity influencing material. The anode or the cathode could be reflective or non-reflective (light-absorbent). This could be achieved by choosing a material with the desired reflectivity properties and the preferred charge conduction and injection properties. An electrically suitably material could be treated (e.g. by surface treatment or incorporation into it of a reflectivity influencing additive) to obtain the desired reflectivity properties.

One specific example is for the rear electrode (the one furthest from a viewer) to be non-reflective. In a device arranged generally as those in figures 1 to 5, this calls for a non-reflective cathode. (In other devices the anode may be the rear electrode). One suitable material for a reflective or non-reflective cathode is LiF:Al. When the Al component of a LiF:Al film is greater than 50% the LiF:Al films are reflective. When the Al component is between 50% and 30% the films are non-reflective. When the Al component is <30% the films are semi-transparent but also have very high resistivities. Therefore, in the range 50:50 to 70:30 LiF:Al LiF/Al films are useful for making a black (non-reflective) cathode.

An example device having a non-reflective rear electrode (in this case the cathode) can be manufactured as follows. On to a glass substrate a 150nm thick layer of ITO is deposited to act as an anode electrode. Then a 50nm thick layer of PEDOT/PSS is deposited to act as a hole transport layer. Over that an 80nm thick layer of a polyfluorene based electroluminescent polymer is formed. Finally the non-reflective cathode layer is deposited as a 200nm thick layer of co-evaporated LiF and Al, with the LiF:Al evaporation rates being 60:40. On top of this layer a 400nm thick Al layer is deposited. In varying this specific design of device it should be noted that the range of potential thickness for the LiF:Al layer depends on the composition since the greater the proportion of LiF in the layer the more transparent the layer becomes. For layers of composition 60:40 LiF:Al 200nm is just thick enough. A suitable range of thickness is from 50 to 1000nm.

Alternative non-reflective cathode materials include generally fluorides and oxides of low work function metals such as Li, Ca, Mg, Cs, preferably together with an inherently highly conductive metal such as Al or Cu (although in some situations Cu may be less preferred because of its tendency to quench polymers' electroluminescence). Specific examples include CsF, MgF, CaF, LiO, CaO, which could be co-evaporated with Al or sputtered from a composite target including Al. The required ratios of the conductor (Al) with the insulating fluorides and oxides can easily be determined by experimentation in each case but might be expected to be similar to those discussed for the LiF:Al system above. Another alternative route to a low reflectivity or non-reflective or cathode is to co-evaporate or sputter a low work function material with carbon. Examples include the low work function metals Ca, Li etc and also the fluorides and oxides listed above.

Figure 6 is a plan view and figure 7 a cross-sectional view of another alternative device. The device comprises an anode electrode 60, a hole transport layer 62, a cathode electrode 63, a light-emissive layer 64 and a distributed Bragg reflector (DBR) layer 65. The DBR is located on the non-viewing side of the light-emissive

layer. The bulk (66) of the cathode 63 is located on the non-viewing side of the DBR. To allow charge to pass from the bulk of the cathode to the light-emissive region cathode vias 67 are provided through the DBR. The vias occupy a relatively small proportion of the area of the device: for example around 15% to 5%. To even out charge injection into the emissive layer a further layer 68 of the cathode which is sufficiently thin to be transparent is provided between the DBR and the light-emitting region. If the DBR were conductive, or the vias were closely spaced, or uniformity could otherwise be achieved then the layer 68 could be omitted. The mesh-like arrangement of vias (see figure 6) could be formed by means of deposition through a shadow mask.

A DBR comprises of a stack of regularly alternating higher- and lower-refractive index dielectrics (light transmissive materials) fabricated to fulfil the Bragg condition for reflection at particular wavelengths. This occurs when the optical path of the periodicity in the dielectric stack corresponds to half a wavelength, and the reflectivity is further optimised when the DBR stack obeys the following equation:

$$\tfrac{1}{2}\lambda = n_1d_1 + n_2d_2,$$

where n_1, n_2 are the respective refractive indices; d_1, d_2 are the corresponding component film thicknesses in the DBR; and λ is the desired reflection wavelength. Figure 8 shows the reflectivity of a DBR against wavelength, the reflectivity peaking at that optimum and being much lower for other wavelengths.

In the device of figures 6 and 7 the DBR is arranged so that the emission wavelength of the light-emissive layer (or its principal emission wavelength) lies within the reflectivity peak of the DBR, and most preferably at or near the maximum reflectivity of the DBR. The effect of this is that the DBR can act to increase the contrast of the device without significantly reducing its efficiency. Light emitted rearwards from the light-emissive layer is reflected efficiently (e.g. with around 95% to 100% reflectivity) back towards a viewer by the DBR. Incident light that is not at or near the emission wavelength of the light-emitting layer, and therefore not within the reflectivity peak of the DBR, is reflected much less (e.g.

only 5% to 10%) and tends to be absorbed by the DBR, improving the contrast of the device. The peaky reflectivity of the DBR may also serve to enhance colour purity of the emission from the device.

The vias may be reflective to a range of wavelengths, so it is preferred to minimise the area occupied by the vias, for example to below 15% and preferably below 10%.

Some variations on the devices described above will now be described. In any of the devices one or more charge transport layers (e.g. layers 15, 70, 71) may be formed between the light-emissive layer and either or both of the electrodes to assist charge transport between the respective electrode and the light-emissive layer and/or to resist charge transport in the opposite direction. The principles described above could be applied to other types of organic or inorganic display devices. One specific alternative example is the class of display devices that use sublimed molecular films for light emission, as described for example in "Organic Electroluminescent Diodes", C. W. Tang and S. A. VanSlyke, Appl. Phys. Lett. 51, 913-915 (1987). The locations of the electrodes could be reversed so that the cathode is located at the front of the display (closest to the viewer) and the anode is at the back. Other materials or classes of materials could be used instead of those mentioned above, although this may impair performance of the devices.

The applicant draws attention to the fact that the present invention may include any feature or combination of features disclosed herein either implicitly or explicitly or any generalisation thereof, without limitation to the scope of any of the present claims. In view of the foregoing description it will be evident to a person skilled in the art that various modifications may be made within the scope of the invention.

CLAIMS

1. A light-emissive device comprising:

a light-emissive region;

a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and

a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type;

and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light absorbent layer comprising graphite and/or a fluoride or oxide of a low work function metal.

2. A light-emissive device as claimed in claim 1, wherein the first electrode is at least partially light-transmissive.

3. A light-emissive device as claimed in claim 1 or 2, wherein the reflectivity influencing structure is located on the opposite side of the second electrode from the light-emissive region.

4. A light-emissive device as claimed in claim 3, wherein the second electrode is at least partially light-transmissive.

5. A light-emissive device as claimed in claim 3 or 4, wherein the thickness of the second electrode is less than 30nm.

6. A light-emissive device as claimed in any of claims 3 to 5, wherein the reflectivity-influencing structure is adjacent the second electrode.

7. A light-emissive device as claimed in claim 1 or 2, wherein the second electrode provides the reflectivity-influencing structure.

8. A light-emissive device as claimed in claim 7, wherein the second electrode comprises a fluoride or oxide of a low work function metal.

9. A light-emissive device as claimed in claim 8, wherein the second electrode comprises aluminium.

10. A light-emissive device as claimed in any preceding claim, wherein the reflectivity-influencing structure is effective to absorb light emitted from the light-emissive region that reaches it through the second electrode and/or incident light.

11. A light-emissive device as claimed in any of claims 7 to 10 as dependant directly or indirectly on claim 6, wherein the presence of the reflectivity-influencing structure adjacent the second electrode renders the second electrode substantially non-reflective to light emitted from the light-emissive region and/or incident light.

12. A light-emissive device as claimed in any preceding claim, wherein the second electrode comprises an electrically conductive material.

13. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises an organic light-emissive material.

14. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises a polymer light-emissive material.

15. A light-emissive device as claimed in any preceding claim, wherein the light-emissive layer comprises a conjugated polymer material.

16. A light-emissive device as claimed in any preceding claim, wherein the reflection-influencing layer is electrically conductive.

17. A light-emissive device comprising:

a light-emissive region;

a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and

a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type;

and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light-reflective layer and a light-transmissive spacing layer between the second electrode and the light-reflective layer, the thickness of the spacing layer being such as to space a reflective plane of the light-reflective layer by approximately half the wavelength of the optical mode of the device from at least part of the light-emissive region.

18. A light-emissive device as claimed in claim 17, wherein the said part of the light-emissive region is a part at which, when the device is in operation, there is significant electron/hole recombination.

19. A light-emissive device as claimed in claim 18, wherein the said part of the light-emissive region is a principal region for electron/hole recombination.

20. A light-emissive device as claimed in any of claims 17 to 19, wherein the said plane of the light-reflective layer is the major surface of the light-reflective layer that is closer to the light-emissive region.

21. A light-emissive device as claimed in any of claims 17 to 20, wherein the second electrode comprises an electrically conductive material.

22. A light-emissive device as claimed in any of claims 17 to 21, wherein the light-emissive layer comprises an organic light-emissive material.

23. A light-emissive device as claimed in any of claims 17 to 22, wherein the light-emissive layer comprises a polymer light-emissive material.

24. A light-emissive device as claimed in any of claims 17 to 23, wherein the light-emissive layer comprises a conjugated polymer material.

25. A light-emissive device as claimed in any of claims 17 to 24, wherein the reflection-influencing layer is electrically conductive.

26. A light-emissive device comprising:

a light-emissive region;

a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type; and

a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type;

and a contrast enhancing structure located on the non-viewing side of the light-emissive region and including a reflective structure having different reflectivity for different wavelengths of incident light, and having a reflectivity peak encompassing an emission wavelength of the light-emissive region.

27. A light-emissive device as claimed in claim 26, wherein the reflective structure is a distributed Bragg reflector.

28. A light-emissive device as claimed in claim 26 or 27, wherein the second electrode comprises a layer located on the non-viewing side of the reflective structure and a plurality of through paths passing through the reflective structure for electrical conduction between the said layer of the second electrode and the light-emissive region.

29. A light-emissive device as claimed in claim 28, wherein the through paths occupy less than 15% of the emissive area of the device.

30. A light-emissive device as claimed in any of claims 26 to 29, wherein the cathode comprises a transparent layer located between the reflective structure and the light-emissive region.

31. A light-emissive device as claimed in claim 30 as dependant on claim 28 or 29, wherein the transparent layer is in contact with the through paths.

32. A light-emissive device as claimed in any of claims 26 to 31, wherein the second electrode comprises an electrically conductive material.

33. A light-emissive device as claimed in any of claims 26 to 32, wherein the light-emissive layer comprises an organic light-emissive material.

34. A light-emissive device as claimed in any of claims 26 to 33, wherein the light-emissive layer comprises a polymer light-emissive material.

35. A light-emissive device as claimed in any of claims 26 to 34, wherein the light-emissive layer comprises a conjugated polymer material.

36. A light-emissive device substantially as herein described with reference to figures 2 to 8 of the accompanying drawings.

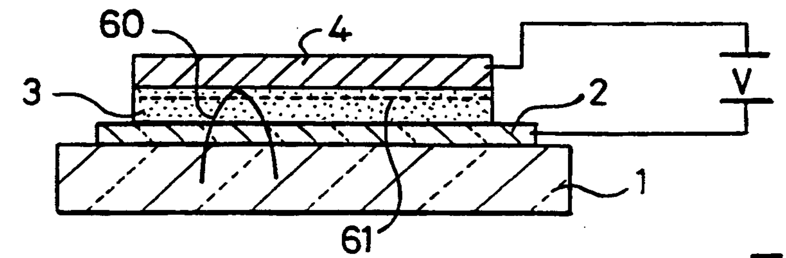

Fig.1

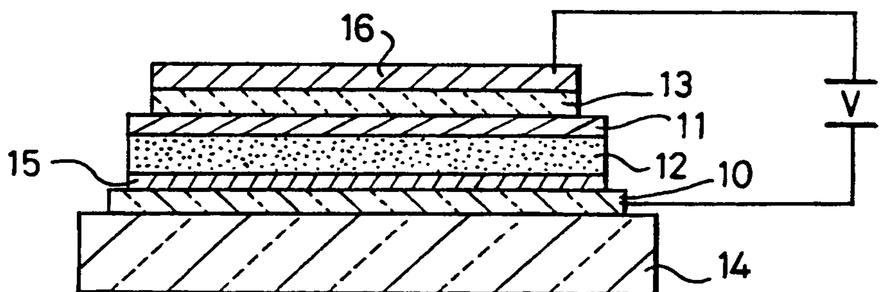

Fig.2

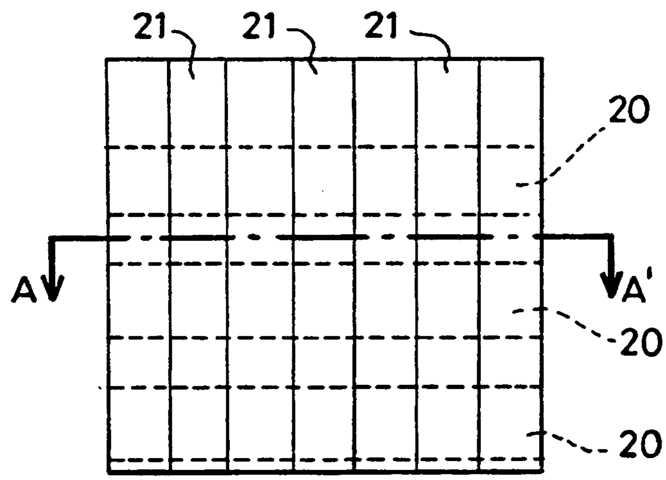

Fig.3

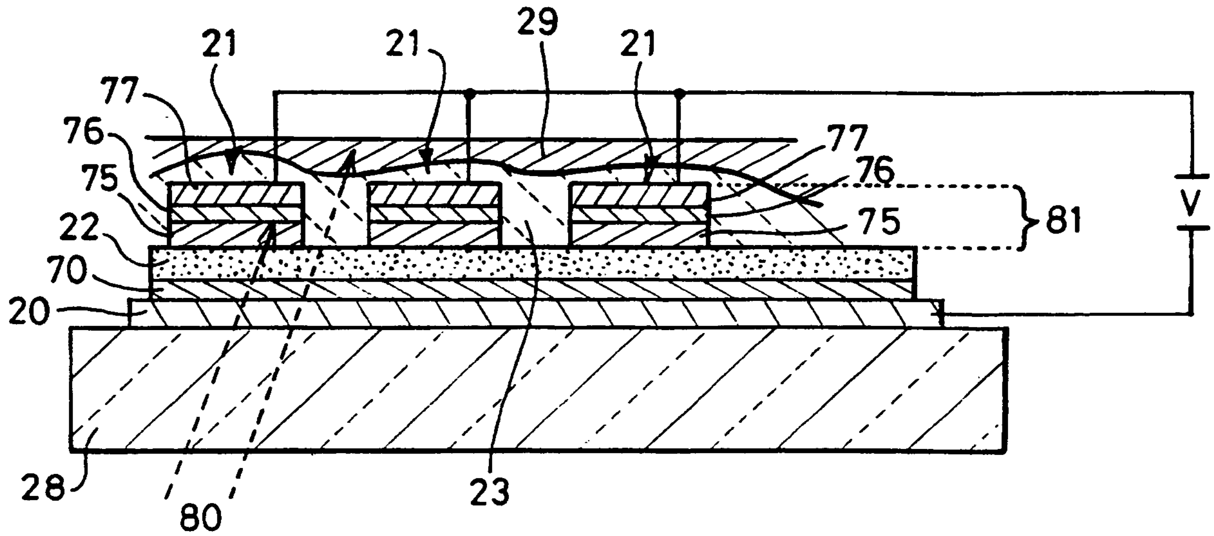
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Fig.4

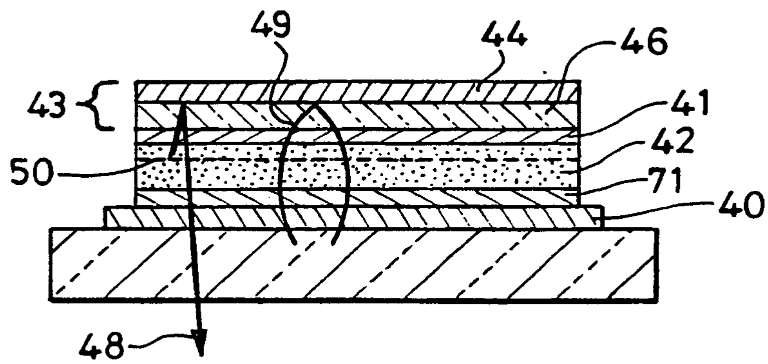
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Fig.5

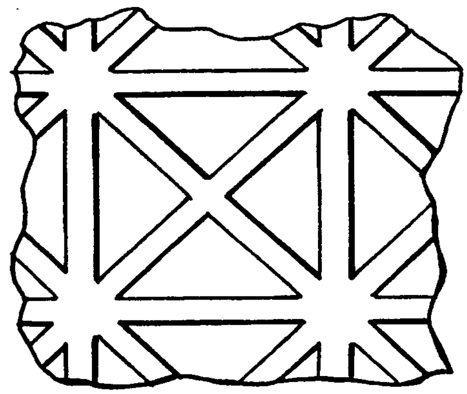

Fig. 6

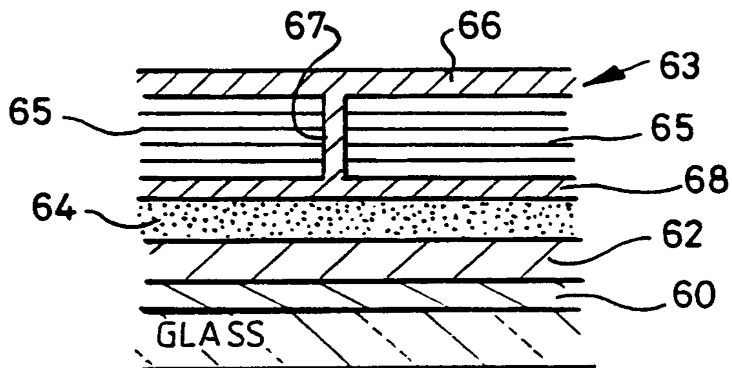

Fig. 7

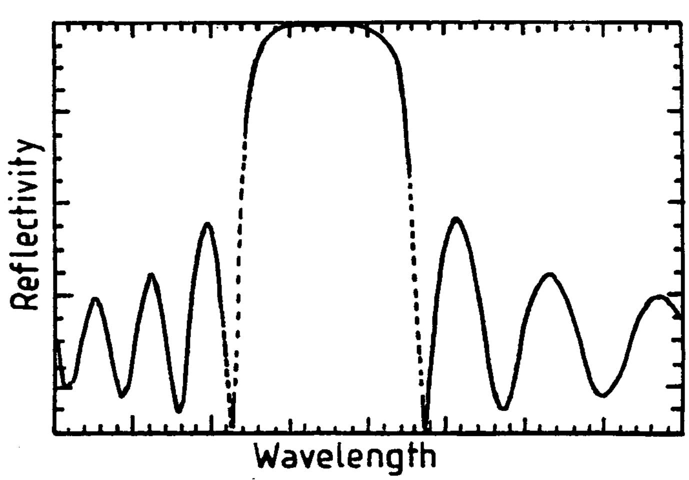

Fig. 8

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 99/04050

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L51/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L H05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 008065 A (TOPPAN PRINTING CO LTD), 12 January 1996 (1996-01-12) abstract column 4, line 14-41 ---	1,2, 7-10,12, 13,36
X	EP 0 483 783 A (GOLD STAR CO) 6 May 1992 (1992-05-06) abstract column 3, line 12 -column 4, line 14; figures ---	1-3,6, 10-12, 16,36
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 March 2000	21/03/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	De Laere, A

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Form PCT/ISA/210 (second sheet) (July 1992)

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DIRR S ET AL: "ORGANIC ELECTRO- AND PHOTOLUMINESCENT MICROCAVITY DEVICES" ADVANCED MATERIALS,DE,VCH VERLAGSGESELLSCHAFT, WEINHEIM, vol. 10, no. 2, 22 January 1998 (1998-01-22), pages 167-171, XP000727865 ISSN: 0935-9648 page 170, column 2, line 41 -page 171, column 1, line 52; figure 5	17-20, 22,25,36
X	EP 0 430 041 A (DAIDO STEEL CO LTD) 5 June 1991 (1991-06-05) abstract; claims; figures	26,32
A	EP 0 838 976 A (TDK CORP) 29 April 1998 (1998-04-29) column 7, line 35-45	1-4,6,8, 10-13
A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 12, 26 December 1996 (1996-12-26) -& JP 08 222374 A (IDEMITSU KOSAN CO LTD), 30 August 1996 (1996-08-30) abstract	1,2,6,7, 10-13,16
A	PATENT ABSTRACTS OF JAPAN vol. 018, no. 195 (E-1533), 5 April 1994 (1994-04-05) -& JP 06 005367 A (PIONEER ELECTRON CORP), 14 January 1994 (1994-01-14) abstract; figures	1-4,6, 10-12
A	GYOUTOKU A ET AL: "Organic electroluminescent dot-matrix display using carbon underlayer" PROCEEDINGS OF THE 1997 INTERNATIONAL CONFERENCE ON ELECTROLUMINESCENCE OF MOLECULAR MATERIALS AND RELATED PHENOMENA;FUKUOKA, JPN MAY 21-24 1997, vol. 91, no. 1-3, 21 May 1997 (1997-05-21), pages 73-75, XP000890057 Synth Met;Synthetic Metals Dec 1997 Elsevier Science S.A., Lausanne, Switzerland the whole document	1

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	JABBOUR G E ET AL: "ALUMINUM BASED CATHODE STRUCTURE FOR ENHANCED ELECTRON INJECTION INELECTROLUMINESCENT ORGANIC DEVICES" APPLIED PHYSICS LETTERS,US,AMERICAN INSTITUTE OF PHYSICS. NEW YORK, vol. 73, no. 9, 31 August 1998 (1998-08-31), pages 1185-1187, XP000781203 ISSN: 0003-6951 abstract ---	1,7-9
A	US 5 674 636 A (MILLER TIMOTHY MARK ET AL) 7 October 1997 (1997-10-07) column 6, line 21-43 -----	17-22

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/GB 99/04050

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 08008065 A	12-01-1996	NONE	
EP 0483783 A	06-05-1992	KR 9310129 B	14-10-1993
		DE 69122030 D	17-10-1996
		DE 69122030 T	06-02-1997
		JP 2117000 C	06-12-1996
		JP 4264390 A	21-09-1992
		JP 8024070 B	06-03-1996
		US 5352543 A	04-10-1994
EP 0430041 A	05-06-1991	JP 2720554 B	04-03-1998
		JP 3163882 A	15-07-1991
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		CA 2030368 A	23-05-1991
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		DE 69025273 T	11-07-1996
		US 5132750 A	21-07-1992
EP 0838976 A	29-04-1998	JP 10125469 A	15-05-1998
		US 5969474 A	19-10-1999
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JP 06005367 A	14-01-1994	NONE	
US 5674636 A	07-10-1997	US 5478658 A	26-12-1995
		DE 69510863 D	26-08-1999
		DE 69510863 T	13-01-2000
		EP 0683623 A	22-11-1995
		JP 7320864 A	08-12-1995

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ATENT COOPERATION TRI TY

From the INTERNATIONAL BUREAU

PCT

To:

HARTWELL, Ian, Peter
Cambridge Display Technology Ltd.
Greenwich House
Madingley Rise
Madingley Road
Cambridge CB3 0HJ
ROYAUME-UNI

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

Date of mailing (day/month/year) 17 November 2000 (17.11.00)	
Applicant's or agent's file reference 76	**IMPORTANT NOTIFICATION**
International application No. PCT/GB99/04050	**International filing date** (day/month/year) 07 December 1999 (07.12.99)

1. The following indications appeared on record concerning:

[X] the applicant [X] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residenc
BERGER, Paul 17 West Ridge Court Newark, DE 19711 United States of America	US	US
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [X] the residence

Name and Address	State of Nationality	State of Residence
BERGER, Paul Cambridge Display Technology Ltd Greenwich House, Madingley Rise Madingley Road CAMBRIDGE CB3 0HJ United Kingdom	US	GB
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[ ] the International Searching Authority
[X] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[X] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Maria Victoria CORTIELLO Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Assistant Commissioner for Patents
United States Patent and Trademark Office
Box PCT
Washington, D.C.20231
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 11 August 2000 (11.08.00)	
International application No. PCT/GB99/04050	**Applicant's or agent's file reference** 76
International filing date (day/month/year) 07 December 1999 (07.12.99)	**Priority date** (day/month/year) 08 December 1998 (08.12.98)
Applicant BERGER, Paul et al	

1. The designated Office is hereby notified of its election made:

   [X] in the demand filed with the International Preliminary Examining Authority on:

   30 June 2000 (30.06.00)

   [ ] in a notice effecting later election filed with the International Bureau on:

   ____

2. The election [X] was
   [ ] was not

   made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland** Facsimile No.: (41-22) 740.14.35	Authorized officer Pascal Piriou Telephone No.: (41-22) 338.83.38

REC'D 07 MAR 2001 WIPO PCT

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PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	FOR FURTHER ACTION	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
CDT 076 PCT		
International application No. PCT/GB99/04050	International filing date (day/month/year) 07/12/1999	Priority date (day/month/year) 08/12/1998
International Patent Classification (IPC) or national classification and IPC H01L51/20		
Applicant CAMBRIDGE DISPLAY TECHNOLOGY LTD. et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 12 sheets, including this cover sheet.

☐ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

These annexes consist of a total of sheets.

3. This report contains indications relating to the following items:

- I ☒ Basis of the report
- II ☐ Priority
- III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- IV ☒ Lack of unity of invention
- V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations suporting such statement
- VI ☐ Certain documents cited
- VII ☒ Certain defects in the international application
- VIII ☒ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
30/06/2000	02.03.2001
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Götz, A Telephone No. +49 89 2399 2498

I. Basis of th r port

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments (Rules 70.16 and 70.17).)*:
   Description, pages:

   1-15 as published

   Claims, No.:

   1-36 as published

   Drawings, sheets:

   1/3-3/3 as published

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   - ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
   - ☐ the language of publication of the international application (under Rule 48.3(b)).
   - ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   - ☐ contained in the international application in written form.
   - ☐ filed together with the international application in computer readable form.
   - ☐ furnished subsequently to this Authority in written form.
   - ☐ furnished subsequently to this Authority in computer readable form.
   - ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   - ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   - ☐ the description, pages:
   - ☐ the claims, Nos.:

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

   ☐ restricted the claims.

   ☐ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☒ This Authority found that the requirement of unity of invention is not complied and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:
   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	15, 19, 24, 28, 29, 31, 35
	No:	Claims	1-14, 16-18, 20-23, 25-27, 30, 32-24, 36
Inventive step (IS)	Yes:	Claims	28, 29, 31
	No:	Claims	15, 19, 24, 35

Industrial applicability (IA)	Yes:	Claims	1-36
	No:	Claims	

2. Citations and explanations
   see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:
see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:
see separate sheet

1 Reference is made to the following documents:

D1: PATENT ABSTRACTS OF JAPAN vol. 1996, no. 05, 31 May 1996 (1996-05-31) -& JP 08 008065 A (TOPPAN PRINTING CO LTD), 12 January 1996 (1996-01-12) -& English language translation

D2: PATENT ABSTRACTS OF JAPAN vol. 1996, no. 12, 26 December 1996 (1996-12-26) -& JP 08 222374 A (IDEMITSU KOSAN CO LTD), 30 August 1996 (1996-08-30) -& English language translation

D3: PATENT ABSTRACTS OF JAPAN vol. 018, no. 195 (E-1533), 5 April 1994 (1994-04-05) -& JP 06 005367 A (PIONEER ELECTRON CORP), 14 January 1994 (1994-01-14) -& English language translation

where?

D4: PATENT ABSTRACTS OF JAPAN vol. 1995 -& JP 07097569 A (SUMITOMO CHEM CO LTD), 11 April 1995 (1995-04-11)

D5: DIRR S ET AL: 'ORGANIC ELECTRO- AND PHOTOLUMINESCENT MICROCAVITY DEVICES' ADVANCED MATERIALS, DE, VCH VERLAGSGESELLSCHAFT, WEINHEIM, vol. 10, no. 2, 22 January 1998 (1998-01-22), pages 167-171, XP000727865 ISSN: 0935-9648

D6: EP-A-0 430 041 (DAIDO STEEL CO LTD) 5 June 1991 (1991-06-05)

D7: US-A-5 674 636 (DODABALAPUR ANANTH ET AL) 7 October 1997 (1997-10-07)

The document D4 was not cited in the international search report.

<u>Re Item IV</u>

Lack of unity of invention

2 The independent claims 1, 17 and 26 are not novel, see the grounds for this objection below (Item V).
Therefore the requisite unity of invention (Rule 13.1 PCT) does not exist inasmuch as a technical relationship involving one or more of the same or corresponding special technical features in the sense of Rule 13.2 PCT does not exist between the subject-matter of claims 1, 17 and 26.

R It m V

Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

3 The subject-matter of independent claim 1 of the present application is not new in the sense of Article 33(2) PCT.

The document D1 discloses:

- a light-emissive device comprising (cf. Fig. 1 and English-language abstract, paragraph "CONSTITUTION"):
- a light-emissive region (cf. Fig. 1, reference sign 3o);
- a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type (cf. Fig. 1, reference sign 2); and
- a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type (cf. Fig. 1, reference sign 4);
- and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light-absorbent layer (cf. Fig. 1, reference sign 4a) comprising graphite and/or fluoride or oxide of a low work function metal (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21). Hence, all the features of claim 1 are known from D1.

It is noted that the alternative of graphite as light-absorbent layer material is not explicitly stated in D1, but carbon is mentioned (cf. Japanese Application JP 08 008065 A, column 3, lines 2-10).

It is noted that D2 also contains all the technical features of claim 1 (cf. Fig. 1, English-language abstract and JP 08 222374 A, column 10, lines 43-44). In D2 graphite as material for the reflectivity-influencing structure is explicitly mentioned.

4 Dependent claims 2-16 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, the reasons being as follows:

Claim 2: The feature of the first electrode being at least partially light-transmissive is known from D1 (cf. English-language abstract, paragraph "CONSTITUTION", line 2).

Claims 3-5: The features of claims 3 to 5 are known from D1 (cf. Japanese Application JP 08 008065 A, column 3, lines 2-17). Moreover, the embodiment of Fig. 2 of D1 can also be read onto claims 3-5. The layer 4c in Fig. 2 is a conductive layer of very low thickness (monoatomic layer to 20 nm thickness) and is located in-between the light emissive layer and the light-absorbent layer. Hence when the layer 4c in Fig. 2 is seen as the "electrode", then the embodiment of Fig. 2 contains all the features of claims 1-5.
Furthermore in D3 the features of claims 3 and 4 are explicitly disclosed (cf. Fig. 4 and JP 06 005367 A, column 2, line 42 - column 3, line 1).

Claim 6: In Fig. 1 of D1 the reflectivity-influencing structure is adjacent the second electrode (cf. reference signs 4a and 4b in Fig. 1).

Claim 7: In Fig. 1 of D1 the second electrode (reference sign 4 in Fig. 1) provides the reflectivity-influencing structure. Also in D2 the possibility of making the second electrode itself light-absorbing is explicitly described (cf. Fig. 2 and description thereof).

Claim 8: In D1 the electrode (reference sign 4 in Fig. 1) comprises an oxide of a low work function metal (cf. Japanese Application JP 08 008065 A, column 4, lines 14-21).

Claim 9: In D1 the electrode (reference sign 4 in Fig. 1) comprises aluminium (cf. Japanese Application JP 08 008065 A, column 4, lines 34-41).

Claim 10: In D1 the reflectivity-influencing structure is effective to absorb light emitted from the light-emissive region that reaches it through the second electrode and/or incident light (cf. Japanese Application JP 08 008065 A, column 5, lines 16-19).

Claim 11: In D1 the second electrode is rendered substantially non-reflective to light emitted from the light-emissive region and incident light (cf. Japanese Application JP 08 008065 A, column 5, lines 16-19).

Claim 12: In D1 the second electrode comprises an electrically conductive

material (cf. Fig. 1, reference sign 4b).

Claim 13: In D1 the light-emissive layer comprises an organic light-emissive material (cf. Fig.1, reference sign 3o and Japanese Application JP 08 008065 A, column 1, lines 2-6).

Claim 14: In D1 the light-emissive layer comprises a polymer light-emissive material (cf. Japanese Application JP 08 008065 A, column 9, lines 15-25).

Claim 15: Conjugated polymer material for the light-emissive layer in organic electroluminescent devices is known (cf. D2: JP 08 222374, column 8, lines 16-22 and D4: English-language abstract, paragraph "PURPOSE").

Claim 16: In D1 the reflection-influencing layer is electrically conductive (cf. Japanese Application JP 08 008065 A, column 3, lines 24-28).

5 The subject-matter of independent claim 17 of the present application is not new in the sense of Article 33(2) PCT.
The document D1 discloses:
- a light-emissive device comprising (cf. Fig. 2 and English-language abstract, paragraph "CONSTITUTION")):
- a light-emissive region (cf. Fig. 2, reference sign 3o);
- a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type (cf. Fig. 2, reference sign 2); and
- a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type (cf. Fig. 2, reference sign 4);
- and wherein there is a reflectivity-influencing structure located on the non-viewing side of the light-emissive region and including a light-reflective layer (cf. Fig. 2, reference sign 4b and JP 08 008065 A, column 5, lines 16-34) and a light-transmissive spacing layer (cf. Fig. 2, reference sign 4a and JP 08 008065 A, column 5, lines 16-34 and lines 42-47) between the second electrode and the light-reflective layer, the thickness of the spacing layer being such as to space a reflective plane of the light-reflective layer by approximately half the wavelength of the optical mode of the device from at least part of the light-emissive region (cf. JP 08 008065 A, column 5, lines 16-34). Hence, all the features of claim 17 are

known from D1.

It is noted that D5 also contains all the technical features of claim 17 (cf. Fig. 5 and right column on page 170, last paragraph - right column on page 171, first paragraph).

6 Dependent claims 18-25 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, the reasons being as follows:

Claim 18: Nor in D1 neither in D5 is the recombination of electrons and holes that takes place in the light-emissive region mentioned explicitly. This feature is however considered implicitly disclosed since it is known that the type of device concerned relies on light emission caused by recombination of electrons and holes.

Claim 19: It is obvious that half-wavelength distance is chosen from a principal electron/hole recombination region.

The technical features of claims 20, 21 and 25 are disclosed in D1 (cf. JP 08 008065 A, column 5, lines 16-34).

Claim 22: In D1 the light-emissive layer comprises an organic light-emissive material (cf. Fig. 2, reference sign 3o and Japanese Application JP 08 008065 A, column 1, lines 2-6).

Claim 23: In D1 the light-emissive layer comprises a polymer light-emissive material (cf. Japanese Application JP 08 008065 A, column 9, lines 15-25).

Claim 24: Conjugated polymer material for the light-emissive layer in organic electroluminescent devices is known (cf. D2: JP 08 222374, column 8, lines 16-22 and D4: English-language abstract, paragraph "PURPOSE").

7 The subject-matter of independent claim 26 of the present application is not new in the sense of Article 33(2) PCT.

The document D6 discloses:
- a light-emissive device (cf. Fig. 2 and description thereof) comprising:
- a light-emissive region (cf. Fig. 2, reference sign 20);
- a first electrode located on a viewing side of the light-emissive region for injecting charge carriers of a first type (cf. Fig. 2, reference sign 28); and
- a second electrode located on a non-viewing side of the light-emissive region for injecting charge carriers of a second type (cf. Fig. 2, reference sign 26);
- and a contrast enhancing structure located on the non-viewing side of the light-emissive region (cf. Fig. 2, reference sign 16) and including a reflective structure having different reflectivity for different wavelengths of incident light, and having a reflectivity peak encompassing an emission wavelength of the light-emissive region (cf. Figs. 6 and 7). Hence, all the features of claim 26 are known from D6.

It is noted that D1 also contains all the technical features of claim 26 (cf. JP 08 008065 A, column 5, lines 16-34).

8 Dependent claims 27 and 30-35 do not contain any features which, in combination with the features of any claim to which they refer, meet the requirements of the PCT in respect of novelty and/or inventive step, the reasons being as follows:

Claim 27: In D6 the reflective structure is a distributed Bragg reflector (cf. column 7, line 48 - column 8, line 8). The distribute Bragg reflector is here called "wave interference type reflector". It is further noted that distributed Bragg reflectors integrated with organic electroluminescent devices are also known (cf. D5, Fig. 3a and D7, Figs. 1 and 2). The devices disclosed in D5 and D7 on the one hand and the device claimed in claim 27 on the other hand differ in that the distributed Bragg reflectors in D5 and D7 are located on the viewing side of the light-emissive region.

Claim 30: D1 discloses the cathode (cf. Fig. 2, reference sign 4) comprising a transparent layer (cf. Fig. 2, reference sign 4a and JP 08 008065 A, column 5, lines 42-47) located between the reflective structure (cf. Fig. 2, reference sign 4b) and the light-emissive region (cf. Fig. 2, reference sign 3o) in combination with all the features of claim 26.

Claim 32: In D1 the second electrode comprises an electrically conductive material (cf. Fig. 2, reference sign 4b).

Claim 33: In D1 the light-emissive layer comprises an organic light-emissive material (cf. Fig.2, reference sign 3o and Japanese Application JP 08 008065 A, column 1, lines 2-6).

Claim 34: In D1 the light-emissive layer comprises a polymer light-emissive material (cf. Japanese Application JP 08 008065 A, column 9, lines 15-25).

Claim 35: Conjugated polymer material for the light-emissive layer in organic electroluminescent devices is known (cf. D2: JP 08 222374, column 8, lines 16-22 and D4: English-language abstract, paragraph "PURPOSE").

9 None of D1-D7 discloses all the features of dependent claim 28 in combination with the features of independent claim 26. Therefore the subject-matter of claim 28 in combination with claim 26 is new in the sense of Article 33(2) PCT. In particular, the feature of a plurality of through paths passing through the reflective structure for electrical conduction between the layer of the second electrode and the light-emissive region is not disclosed in the prior art at hand. The vias improve the electrical connection among the rear electrode and the light-emissive layer. Since this feature is not suggested in any of the documents at hand claim 28 in combination with claim 26 also fulfills the requirement of Article 33(3) PCT (inventive step).

10 Claims 29 and 31 are dependent on claim 28 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

Re Item VII

Certain defects in the international application

11 Claim 36 contains a reference to the drawings. According to Rule 6.2(a) PCT, claims should not contain such references.

12 Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art

disclosed in the documents D1-D7 is not mentioned in the description, nor are these documents identified therein.

13 The independent claims are not in the two-part form in accordance with Rule 6.3(b) PCT.

14 The features of the claims are not provided with reference signs placed in parentheses (Rule 6.2(b) PCT).

15 The sign */⌀ in line 19 on page 8 has no recognised meaning.

<u>Re Item VIII</u>

Certain observations on the international application

16 The vague and imprecise statement in the description on page 15, last paragraph implies that the subject-matter for which protection is sought may be different to that defined by the claims, thereby resulting in lack of clarity (Article 6 PCT) when used to interpret them (see also the PCT Guidelines, III-4.3a).

17 In claim 11 the expression "... claims 7 to 10 as dependent directly or indirectly on claim 6 ..." is unclear (Article 6 PCT), in particular because claims 7-9 actually do not depend on claim 6.